confinement, the moisture-laden air carried downstream to the HEPA filters can seriously degrade filter performance—at a time when high-efficiency filter performance is crucial.

### 2.3.4 Filter Strength

The remaining strength of HEPA filters must be adequately considered, especially under challenging conditions, such as having to cope with a fire. Making this determination is particularly difficult, however, since no nondestructive in-place test is available. Further, many unpredictable factors can degrade the filter installation's strength without the operators' knowledge. Filter strength is affected by such factors as manufacturing variables, aging, loss of binder, loss of water-repellent capability, shelf life, history of prior wetting, exposure to high temperature, exposure to high radiation, exposure to chemicals, and exposure to moisture-laden air (Frethold et al., July 14, 1997; Bergman et al., 1994; Carbaugh, 1982; Johnson et al., 1988; Moeller, 1982; First, 1996). While many of these factors have been investigated, a quantitative assessment does not appear possible at this time. More important, a conservative limit on filter life is not currently mandated by DOE.

### 2.3.5 Air Leaks

Careful design, attentive operation, and disciplined maintenance of a HEPA installation can be negated by air leaks in the negative pressure region of the system downstream of the filters and upstream of the fans. Leaking gaskets, fan seals, and damper actuator penetrations are particularly vulnerable. These regions are not routinely checked for leaks (Frethold et al., July 14, 1997; Roberson, March 3, 1997). When RFETS addressed this issue, such leaks were found.

## 2.4 RESULTS OF PRIOR RESEARCH

The literature is replete with studies that examine possible negative influences on HEPA filter performance (Frethold et al., July 14, 1997; Bergman et al., 1994; Johnson et al., 1988; Robinson et al., 1985). The data presented in these studies are based almost entirely on HEPA filters less than 15 years old. A few of the filters examined in the studies were 15–20 years old, and a very few were older than that (the age of these filters typically includes both shelf and service life).

Frethold's work (Appendix 4, Figure 4-1) (Frethold et al., July 14, 1997) shows some unused but aged filters with less than minimum specified initial tensile strength of 2.5 pounds per inch for unfolded media and 2.0 pounds per inch for folded media. "Folded" versus "unfolded" here is significant because the most commonly observed failure point on a HEPA filter is on the downstream fold. Further, Frethold's work (Figure 6-1) reveals variability for this parameter by factors of 2–3 for the same manufacturer.

The loss of water-repellent capability has also been observed by several investigators. This can be a significant factor if moisture carryover or sprays from firefighting efforts impinge on the filters. Filters untreated for water repellency are expected to absorb some fraction of the





impinging moisture or water. This moisture absorption can dramatically increase the pressure drop across the filter and lead to filter failures. According to Frethold (Figures 2-1 and 2-2), loss of the ability to repel water does not appear to be a problem in storage, but can be significant in service. Johnson's data (Johnson et al., 1988) show a 57–100 percent loss of water-repellent capability among filters in service for 13–14 years.

These data suggest that remaining strength and ability to repel water are important considerations for continued HEPA filter use, but it is not possible to specify an exact service life. Qualitatively, however, the data clearly indicate that filters cannot stay in service indefinitely. Since an exact service life cannot be determined and data variability is significant, individual vulnerability assessments that examine the expected efficiency, life, and mission for installed HEPA filters would appear to be desirable.

Frethold (Appendix 3) presents the results of soaking a HEPA filter, drying it, and then testing the dried media for tensile strength. This investigation was designed to simulate the effects of direct impingement spray testing for fire protection purposes. The results revealed that one soaking can reduce the strength of the filter media to less than the initial purchase specification value. Additional tests conducted by Frethold without presoaking also demonstrated weakening of the filters. On the basis of these data, the safety significance of the application, and a consideration of future building use, one DOE site (RFETS) decided to replace various previously wetted HEPA stages (in Buildings 371 and 707). The choice appears to have been a prudent one.

It should be noted that most of the investigations cited above were carried out under funding provided by DOE and its predecessor agencies. Today almost no funding is available for conducting such investigations, even though there are many unanswered questions. No programmatic office within DOE has stepped forward to set priorities regarding the additional information required.

Taken collectively, the published data also suggest that there could be some unused HEPA filters in storage—ready to be installed in safety systems—that would not meet newly purchased filter specifications. Further, the data suggest that installed HEPA filters could be so degraded by age and loss of ability to repel water that they might not perform their expected safety function when called upon to do so.

Several attempts have been made to establish an age limit for HEPA filters, taking into consideration the weaknesses observed during testing. First (1996) of the Harvard Air Cleaning Laboratory recommends 5 years for HEPA filters used in biological cabinets. The Savannah River Site has a 5-year limit in place, including both shelf life and service life. LLNL previously proposed an 8-year limit, and is currently proposing a 10-year limit. Some DOE facilities have filters in service that were installed more than 20 years ago. A prominent filter manufacturer claims a 3-year shelf life, but only under proper storage conditions. No other age limits at DOE facilities have been proposed to date. Nor have any additional routine measurements or assessments to evaluate the residual strength of HEPA filters been proposed.

## 3. REVIVING THE INFRASTRUCTURE

To be effective, any management system requires feedback. In the case of HEPA filters, there are many indications that an acceptable program for feedback of experience is either absent or seriously degraded. At a time when additional HEPA filter investigations may be called for, budgets have been cut to the point that meaningful research in this area is no longer possible. Moreover, after nearly 50 years of continuing support for the Nuclear Air Cleaning Conferences, DOE has decided to withdraw support for future conferences, seriously compromising opportunities for feedback from peer review and a free exchange of ideas. Reconsideration of this decision is warranted in order to restore vigor to this important safety-related research area and to provide better assurance of adequate information exchange on the subject of ventilation filtration. This report should be regarded as an impetus for a revitalized feedback and improvement program for DOE's HEPA filter program, following the tenets set forth in Board Recommendations 95-2, *Safety Management*, and 98-1, *Integrated Safety Management*.

There is physical evidence that some HEPA filters presently in service may be too weak to perform their safety function effectively (Frethold et al., July 14, 1997), and there is continued reliance on a field test that provides no information on the filters' remaining physical strength. Indeed, physical evidence suggests that even unused but aged filters may not meet minimum strength requirements. These findings indicate a need to strengthen quality assurance and quality control programs for HEPA filters. At the same time, however:

- The QPL laboratory committed to by senior DOE management is not yet in place.
- The existence of the last remaining FTF is tenuous.
- An updated Nuclear Air Cleaning Handbook, a draft revision of which was originally committed to by December 1996, is not yet available.
- There is a serious need to update a related DOE Handbook to correct errors that could lead to nonconservative analyses, as has occurred at least once.

To address these issues and restore vitality to its filter program, DOE should give serious consideration to the following actions:

- Designate a location and firmly commit to providing funding, personnel and physical resources, and continued programmatic support for a replacement for the QPL laboratory, on an expedited schedule.
- Ensure continued operation of the Oak Ridge FTF.
- Identify needed resources and assign responsibility for early publication of a revised Nuclear Air Cleaning Handbook, in order to make accurate, up-to-date guidance on the subject available.









- Revise, update, and implement DOE-HDBK-3010-94 to eliminate confusing guidance regarding the performance characteristics of installed HEPA filters, and to improve the quality and reliability of assumptions supporting safety analyses involving these critical components of confinement systems protecting workers, the public, and the environment.
- Establish a conservative maximum age limit for HEPA filters involved in safety-related service. Such a limit should be established, simply because the filters degrade with time, and only 10–15 years of meaningful data is available to justify extended service life. Any age limit established should be supported by a systematic evaluation of how the strength of HEPA filters varies over time, for both installed filters and those in storage.

The above actions are called for to restore DOE's failing infrastructure supporting its HEPA filter program. At this time, however, higher priority should be attached to prompt completion of a vulnerability assessment of each facility relying on HEPA filters for accident mitigation. Filters specifically required to operate (and those being stored in place that could interact with these filters—as in the case of standby, bypass filter banks) in a stressed situation (e.g., in fires, during sprays, or in high temperatures) while called upon to perform a safety function should be assessed for their ability to perform acceptably. Installed filters that have already exceeded their useful life should be replaced on a prioritized basis. Finally, systematic evaluations of the anticipated performance of installed HEPA filters compared with the tasks they are expected to perform should be completed. These evaluations should be based on reasonable but conservative assumptions regarding potential mechanisms for filter degradation, pending the conduct of meaningful research aimed at definitively establishing a better understanding of how filter strength varies with time.

This report has described a significantly degraded DOE infrastructure for HEPA filters. Confinement viability demands high dependability of these filters. An acceptable level of reliability can be assured only if the robust infrastructure required to support continued assurance of their performance is restored.

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## GLOSSARY OF ACRONYMS

| Abbreviation | Definition |
|---|---|
| Board | Defense Nuclear Facilities Safety Board |
| DOE | Department of Energy |
| DOP | Dioctalphthalate |
| FTF | Filter Test Facility |
| HEPA | High-Efficiency Particulate Air |
| LLNL | Lawrence Livermore National Laboratory |
| OSR | Operational Safety Requirements |
| QPL | Qualified Products List |
| RFETS | Rocky Flats Environmental Technology Site |
| SAR | Safety Analysis Reports |
| TSR | Technical Safety Requirements |